Endoscope-assisted transsphenoidal puncture of the cavernous sinus for embolization of carotid-cavernous fistula in a neurosurgical hybrid operating suite

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Endovascular embolization is the treatment of choice for carotid-cavernous fistulas (CCFs), but failure to catheterize the cavernous sinus may occur as a result of vessel tortuosity, hypoplasia, or stenosis. In addition to conventional transvenous or transarterial routes, alternative approaches should be considered. The authors present a case in which a straightforward route to the CCF was accessed via transsphenoidal puncture of the cavernous sinus in a neurosurgical hybrid operating suite.

This 82-year-old man presented with severe chemosis and proptosis of the right eye. Digital subtraction angiography revealed a Type B CCF with a feeding artery arising from the meningo-hypophyseal trunk of the right cavernous segment of the internal carotid artery. The CCF drained through a thrombosed right superior ophthalmic vein that ended deep in the orbit; there were no patent sinuses or venous plexuses connecting to the CCF. An endoscope-assisted transsphenoidal puncture created direct access to the nidus for embolization. Embolic agents were deployed through the puncture needle to achieve complete obliteration. Endoscope-assisted transsphenoidal puncture of the cavernous sinus is a feasible alternative to treat difficult-to-access CCFs in a neurosurgical hybrid operating suite.

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KEY WORDS carotid-cavernous fistula; coil; embolization; endonasal; endoscope; endovascular; hybrid surgery; transsphenoidal approach; interventional neurosurgery

CAROTID-CAVERNOUS fistulas (CCFs) are pathologic arteriovenous shunts between the internal carotid artery/external carotid artery (ICA/ECA) and the cavernous sinus (CS). Barrow² classification divides CCFs into 4 categories according to the following anatomical and hemodynamic features: 1) Type A, a direct high-flow shunt between the ICA and the CS; and 2) Types B, C, and D, indirect low-flow dural shunt with arterial feeders from meningeal branches of the ICA, ECA, both ICA and ECA, respectively. These abnormal communications cause anterior and posterior retrograde venous congestion with resultant neuroophthalmic compromise. Intracranial hemorrhage may occur if significant retrograde venous drainage is present. Endovascular therapy is considered the first-line treatment of CCF. Endovascular access to

CCFs includes the transvenous approach via the inferior petrosal sinus or superior ophthalmic vein (SOV) and transarterial catheterization of the feeders. These routes may be difficult to establish in the elderly with vessel tortuosity, hypoplasia, or stenosis, or in cases in which previous embolic agents are in place. For direct embolization of difficult-to-access CCFs, transsphenoidal approaches have been described in 2 cases in the literature, one via sublabial transmaxillary transsphenoidal route⁹ and the other via external transethmoidal transsphenoidal route,¹ neither of which employed a neuroendoscope and both of which required more extended sinus destruction before accessing the nidus (Table 1). More recently, advances in endoscopic endonasal surgery have increased our ability to expose and operate in the CS.^{3,8} However, extended

ABBREVIATIONS CCF = carotid-cavernous fistula; CS = cavernous sinus; DSA = digital subtraction angiography; ECA = external carotid artery; GDC = Guglielmi Detachable Coil; ICA = internal carotid artery; NBCA = *N*-butyl 2-cyanoacrylate; SOV = superior ophthalmic vein.

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TABLE 1. Literature review of transsphenoidal approaches to embolize the cavernous sinus

Authors & Year	Lesion*	Approach	Embolitic Agent	Outcome
Loyo et al., 1987	CCF, Barrow type unknown	Sublabial transmaxillary transsphenoidal	Sealing substance (fibrin & factor VIII)	Not mentioned
Barker et al., 1994	CCF, Barrow Type A	External transthemoidal transsphenoidal	Gianturco coil	Complete obliteration
Current study	CCF, Barrow Type B	Endoscopic endonasal transsphenoidal	Fibered coil, GDC, NBCA	Complete obliteration

endoscopic approaches require a difficult learning curve and carry risks of ICA injury.¹¹ Here, we describe the first case of CCF treated via simple endoscope-assisted transsphenoidal puncture of the CS for direct embolization in a neurosurgical hybrid operating suite.

Case Report

History and Presentation

This 82-year-old man with a medical history of end-stage renal disease, chronic obstructive pulmonary disease, and cerebral infarction experienced double vision and aggravating frontal headaches for 1 year. Severe chemosis and proptosis of the right eye had been noticed for 3 months. The patient denied visual loss and a history of trauma. He had undergone initial treatment for Tolosa-Hunt syndrome.

Radiological Study

Dynamic MR angiography disclosed early opacification of the right CS and engorgement of the right SOV. A CCF was suspected. Digital subtraction angiography (DSA) confirmed the diagnosis of a Type B CCF, with a single small feeding artery arising from the meningohypophyseal trunk of the right cavernous ICA. The inferior and superior petrosal sinuses, basilar plexus, and pterygoid plexus were not patent. The CCF drained through a partially thrombosed right SOV that ended deep in the orbit, without apparent anastomosis to the facial vein (Fig. 1). CT angiography revealed the relationships between the CCF, the ICA, and skull base structures, which helped design the treatment strategy and surgical trajectory (Fig. 2).

Operation and Embolization

Under general anesthesia, the patient was placed supine with his head fixed using a radiolucent head holder and pins in our neurosurgical hybrid operating suite equipped with a robotic angiographic fluoroscopy system (Artis Zeego FD system, Siemens AG). A 5-Fr guiding catheter was inserted into the right ICA through the right femoral artery approach for angiographic guidance.

A simple endoscopic endonasal transsphenoidal approach was performed to reach the medial wall of the CS (Video 1).

VIDEO 1. Video summarizing the patient's brief history, radiological examinations, surgical settings, procedural details/nuances, and outcome. ACP = anterior clinoid process; CTA = CT angiography; MHT = meningohypophyseal trunk; S/S = signs/symptoms. Copyright Yang-Seng Tsuei. Published with permission. Click here to view.

This procedure was carried out through the right nostril by

1 surgeon (2-hand technique) using a rigid neuroendoscope (outer diameter: 4 mm; direction of view: 0°). A nasal speculum was placed to help maintain the surgical corridor. A linear mucosal incision was made on the right side of the sphenoid rostrum where a small opening was created by electric drills. A vascular pedicle nasoseptal flap was not needed. Then, a 17-gauge × 15-cm coaxial introducer needle (Terumo Coaxial Introducer Needle, CareFusion) was inserted through the sphenoid sinus to the medial wall of the CS. Using anatomical landmarks, we checked the entry point to the CS under endoscopic visualization and a neuronavigation system, and it was then reconfirmed by the roadmap view under fluoroscopic visualization with the aid of the robotic angiographic fluoroscopy system. A safe needle trajectory was ensured by superimposing the needle tip and the hub into a “target sign” at the entry point (Fig. 3). The needle was gently hammered through the skull base into the CS. With incremental advancement of the needle, the stylet was removed to assess for blood return.

FIG. 1. DSA revealed a Type B CCF on the right side. **A:** In the anteroposterior view and arterial phase, the blue arrow indicates a CCF located medial to the right ICA. **B:** In the lateral view, the blue arrow shows the CCF posterior to the right cavernous ICA with the feeding artery arising from the meningohypophyseal trunk (red arrow). **C:** In the anteroposterior view and venous phase, the CCF drains ipsilaterally through a partially thrombosed right SOV. There is no communication of the nidus to the contralateral side of the CS or other venous sinus/plexus. **D:** In the lateral view, the right SOV opacifies gradually in the venous phase and ended deep in the orbit, without apparent anastomosis to the facial vein. Figure is available in color online only.

FIG. 2. CT angiography demonstrating the relationship between the CCF, the ICA, the SOV, and skull base structures. **A:** 3D lateral view of the right CS region, showing the fistula point posterior to the cavernous ICA. The venous outflow drained via the CS to the right SOV. **B:** 3D medial view of the right orbit showing the SOV ending abruptly and deeply in the orbit. The axial and coronal cuts revealed that the end of the SOV was located behind the eye and adjacent to the optic nerve. **C:** With a cross-referencing tool, the location of the lesion could be confirmed, which helped us plan the surgical trajectory. Only a thin layer of sphenoid bone covering the inferomedial aspect of the CS and transsphenoidal approach via ipsilateral nostril could provide us with a direct approach to the nidus. Figure is available in color online only.

Blood was seen, and a right ICA angiogram was obtained to determine the relationships between the needle tip, the CCF, and the ICA. For evaluation of the CCF before embolization, contrast was injected through the needle into the nidus (Fig. 4). A microcatheter was inserted through the coaxial introducer needle to deploy platinum framing coils into the CS. The embolic agents used in this case were fibered platinum coils, Guglielmi Detachable Coils (GDCs), and *N*-butyl 2-cyanoacrylate (NBCA). To deploy fibered coils, we loaded a coil into the needle, attached a syringe filled with normal saline to the needle, and flushed the coil into the CS. A stylet could also be used to push the coils. A

microcatheter was inserted through the coaxial introducer needle to deploy GDCs into the CS. It is important to make sure that the fistula point is blocked by coils. After the CCF was densely packed with coils, NBCA was injected to fill the nidus. A follow-up right ICA angiogram demonstrated complete obliteration of the CCF (Fig. 5). Then, the needle was removed, and some tissue glue was applied on the puncture hole.

Postoperative Course

There were no procedure-related complications. The patient's proptosis and chemosis resolved completely a week after the procedure (Fig. 6). His double vision also improved. A 3-month follow-up cerebral angiogram showed persistent occlusion of the fistula.

Discussion

The treatment of indirect CCF is challenging. Endovascular therapy is considered the treatment of choice because of the location and the nature of the disease. Despite improvements in catheter and coil design, the ways to deliver these embolic agents to the nidus remain an issue. CCFs are frequently associated with numerous small-caliber meningeal branches of the ICA and/or the ECA, which makes the transarterial approach much less effective. As to a transvenous approach, the inferior petrosal sinus is the preferred venous route to the CS. Other options include the SOV, superior petrosal sinus, basilar plexus, and pterygoid plexus. These venous routes may be hard to access when the venous structures are too tortuous, stenotic, or thrombosed. In patients harboring isolated CCFs with limited venous outflow, other minimally invasive approaches may be considered.^{4,6,10}

We considered that stereotactic radiosurgery was not an option because the patient's clinical condition was worsening. Endovascular treatment was the option. In our case, DSA revealed a small feeding artery branching from the right meningohypophyseal trunk, which was a difficult transarterial route. Transvenous routes were not possible because the inferior and superior petrosal sinuses, basilar plexus, and pterygoid plexus were not patent. In addition, the patient's SOV ended deep within the orbit behind the eyeball, which was considered suboptimal for a cutdown procedure. Without available conventional transarterial and transvenous routes, other approaches need to be considered. Transorbital puncture to the orbital tissues with existing high venous pressure can result in severe intraorbital hemorrhage and a decrease in visual acuity.^{4,15} Other potential procedure-related risks include optic nerve damage, globe puncture, infection, and laceration of the ICA resulting in direct CCF,⁷ not to mention direct puncture through the ICA.¹⁰ Transovale puncture actually does not allow direct access to the CS because it is not an in-line direction, and ICA injury is a possible complication.⁶ Over the years, we have gained experience and confidence in dealing with different kinds of vascular lesions via hybrid surgery in our neurosurgical hybrid operating suite.^{12–14} Due to the aforementioned reasons, we considered a simple endoscope-assisted transsphenoidal puncture for CCF embolization as a suitable and feasible choice.

FIG. 3. Endoscope-assisted transsphenoidal puncture of the cavernous sinus for CCF embolization in the neurosurgical hybrid operating suite. **A:** A uninostril approach was used. After the sphenoid sinus was entered, the tip of the introducer needle was placed at the point of interest, according to anatomical landmarks under endoscopy. **B:** A safe needle trajectory is confirmed with the aid of the robotic angiographic fluoroscopy system in the roadmap view. In this picture, the needle tip should be moved upward to the point where the red arrow indicates. The needle trajectory should be adjusted in-line with that of the fluoroscopy, which means that the needle tip is superimposed on and at the center of the needle hub (*target sign*). **C:** The actual trajectory used to deploy the coils, the lateral view of which is shown in Fig. 4. **D:** Once the needle was placed properly and the trajectory confirmed, we hammered it into the nidus gradually. With incremental advancement of the needle, the stylet was removed to assess for blood return. **E:** After establishing the transsphenoidal access to the CS, we initiated embolization via the large bore introducer needle. In this picture, a fibered platinum coil is pushed into the CS by a stylet. Figure is available in color online only.

Deploying coils at the fistula point was essential, which not only blocked the arterial flow but also helped further coil packing and glue injection. Small bore needles make changing microcatheters and deploying coils difficult. We suggest using a 17-gauge needle in this procedure to deploy fibered coils and GDCs. A transsphenoidal route obviates concerns about optic nerve damage, intraorbital hemorrhage, and globe puncture due to its inherent entry trajectory. ICA injury can be avoided by both endoscopic and fluoroscopic visualization. Onyx could achieve immediate obliteration of CCF with high rates of success, but cranial neuropathies have been reported to have been seen

FIG. 4. Evaluation and embolization of the CCF. **A:** Contrast was injected through the needle into the nidus. Early and obvious enhancement of the intracranial circulation is noted, and thus we decided not to use Onyx as our embolic agent, in case of reflux. **B:** After initial coil framing of the nidus, the fistula point was blocked by the coils. Further coil packing was performed, and NBCA was also used to supplement the existing coil mass.

FIG. 5. Postembolization angiography. **A and B:** In the anteroposterior and lateral views, no filling of the CCF is seen in the arterial phase. **C and D:** The venous phase also did not reveal any abnormalities.

FIG. 6. Clinical photographs of the patient before and after embolization. **A:** Severe chemosis and proptosis before embolization. **B:** Resolution of chemosis and proptosis 1 week after embolization. Figure is available in color online only.

in 25% of cases, which highlights the real risk of the penetration of Onyx to deep collaterals that supply the cranial nerves as well as the possible direct toxic effects of dimethyl sulfoxide in this region.⁵ We did not use Onyx due to the potential risk of reflux of embolic agents into the ICA and intracranial circulation as well as nutrient arteries feeding cranial nerves. We used NBCA to supplement an existing coil mass after the nidus was densely packed. Placing a balloon in the ICA during the embolization was not warranted in our case.

Obtaining access to CCFs is the most critical step in initiating the treatment. In patients with difficult arterial or venous routes, endoscope-assisted transsphenoidal puncture of the CS may offer an easy and straightforward solution.

Conclusions

Endoscope-assisted transsphenoidal puncture of the cavernous sinus is a feasible alternative to treat difficult-to-access CCFs in a neurosurgical hybrid operating suite.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Tsuei, Chen. Acquisition of data: Tang, Liao, Chen, Shen. Analysis and interpretation of data: Tang, Liao, Shen, CH Lee. Drafting the article: Tang, Liao. Critically revising the article: Tsuei, Liao, Chen, HT Lee. Reviewed submitted version of manuscript: Tsuei, Liao, Chen, CH Lee, HT Lee. Approved the final version of the manuscript on behalf of all authors: Tsuei. Administrative/technical/material support: Shen, CH Lee. Study supervision: Tsuei, HT Lee.

Supplemental Information

Videos

Video 1. <https://vimeo.com/170474660>.

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